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CAMERON STATION, ALEXANDRIA, VIRGINIA



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STEP

AUTHOR: Zadikoy, I. N.

TITLE: Some exact solutions of the energy equation for a plane parallel flow of a viscous incompressible fluid

PERIODICAL: Inzhenerno-fizicheskiy zhurnal, v. 5, no. 10, 1962, 3 - 8

TEXT: The boundary value problem

$$\frac{1}{a} \frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial y^2} + \frac{\mu}{\lambda} \frac{U_0^2}{h^2},$$

$$T(y, 0) = T_0 + \frac{\mu U_0^2}{2\lambda} \frac{y}{h} \left(1 - \frac{y}{h}\right), \quad (3)$$

$$T(0, t) = T_0, \quad T(h, t) = T_1.$$

is solved by the expression

$$\theta = \eta + S\eta(1-\eta) + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^n}{n} \sin(\pi n \eta) \exp(-\pi^2 n^2 \beta),$$

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where $\theta = (T - T_0)/(T_1 - T_0)$, $\beta = at/h^2$, $\eta = y/h$, and $S = (\text{PrE})/2 = \mu^2/2\lambda(T_1 - T_0)$. It is shown that for $S \gg 1$ the cooling of the wall ceases at $\beta_{cr} = \nu t_{cr}/h^2$ and that its heating is due to the dissipation energy of the fluid. The figure illustrates the dependence of β_{cr} on S (the indices 1 and 2 refer to the steady and to the unsteady flow, respectively). For an unsteady flow, the temperature distribution is obtained only for $\text{Pr} \gg 1$,

$$\theta = \eta + S\eta(1-\eta) + (2/\pi) \sum_{n=1}^{\infty} (-1)^n \sin(\pi n \eta) \exp(-\pi^2 n^2 \beta)/n -$$

$$(8/\pi^3) S \sum_{n=1}^{\infty} (2n-1)^{-3} \sin[(2n-1)\pi \eta] \exp[-\pi^2 (2n-1)^2 \beta], \quad (6)$$

and for $\text{Pr} \ll 1$,

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$$\theta = \eta + \frac{2}{\pi} \sum_{k=1}^{\infty} \frac{(-1)^k}{k} \sin(\pi k \eta) \exp(-\pi^2 k^2 \beta) +$$

$$+ S \left\{ (\eta - \eta^2) [1 + 2 \exp(-2\pi^2 \beta)] + \frac{8}{\pi^2} \exp(-\pi^2 \beta) (1 - \cos \pi \eta) - \right.$$

$$\left. \frac{16}{\pi^2} \eta \exp(-\pi^2 \beta) + \frac{1}{\pi^2} (\cos 2\pi \eta - 1) \exp(-2\pi^2 \beta) \right\}. \quad (7)$$

Equation (6) can be used to calculate the temperature distribution in a lubricant ($\text{Pr} \gg 1$) which takes up the play between the crank journal and the bearing when rapid changes occur in the rpm of the shaft. There are 3 figures.

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SUBMITTED: April 18, 1962

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